APERTURE SYNTHESIS MAPS OF CO EMISSION FROM M51

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ABSTRACT

7"-resolution maps of CO emission from the central 2' of M51 have been made with the Owens Valley millimeter-wave interferometer. Relative warm gas from giant molecular clouds is seen largely confined to arms coincident with the dust lanes, forming coherent structure on the scale $\sim$3 Kpc. There is a minimum of CO emission within 400 pc of the center. Integrated CO intensity maps are presented. Non-circular motion of the CO gas is evident from the velocity field.

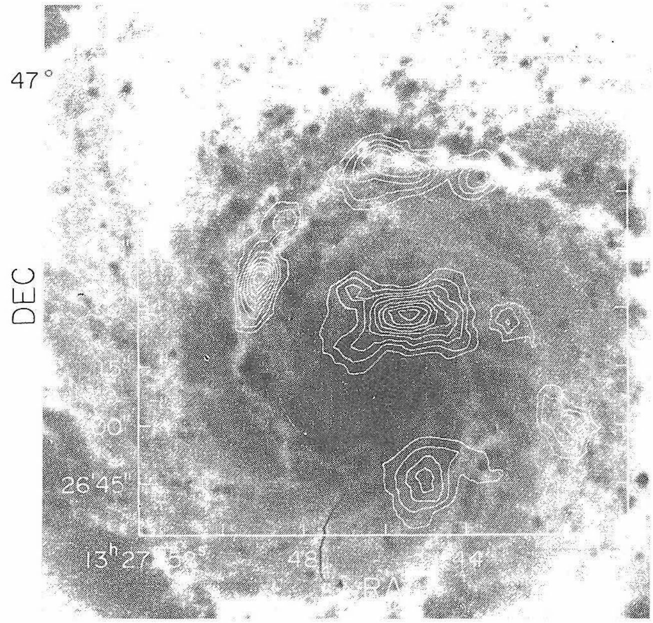
INTRODUCTION

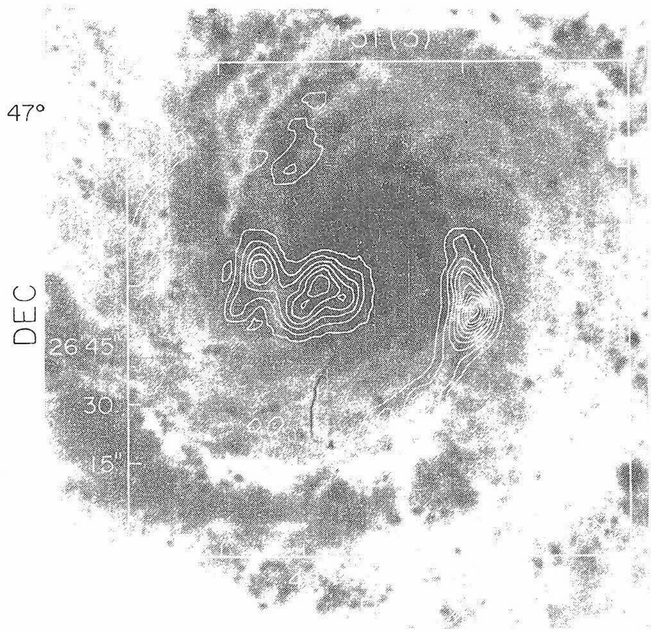
The structure of (late-type) spiral galaxies are most strikingly outlined by "Population I" objects, i.e. young blue stars, HII regions and dust lanes. Molecular gas, being the raw material for star formation, is an important ingredient and tracer of galactic structure; observing its distribution, physical properties and relationship to the "Population I" objects would provide important clues to the mechanisms leading to galactic structure.

The galactic distribution of molecular gas, as traced by CO emission, is best studied in external galaxies that usually provide a more favourable viewing perspective than our Galaxy. While single-telescope observations have been made with resolutions at 30" [1] and 14" [2], details of the molecular distribution in external spiral galaxies are generally not well resolved. At the distance of M51 (10 Mpc), 30" corresponds to 1.5 kpc.

We report here preliminary results of aperture synthesis mapping at $\sim$7" resolution of the CO emission from two overlapping fields covering the central 2' of M51, obtained with the Owens Valley millimeter-wave interferometer [3].

A millimeter-wave interferometer is a very well matched instrument for studying external galaxies: (i) Besides providing the necessary high angular resolution, positional accuracy ($\sim$0.1 of the synthesized beam or $\lesssim$1") of the synthesis maps is much better than the absolute pointing of a large millimeter telescope, making comparisons to other observations more reliable. (ii) Because of the high observing frequency, the brightness temperature sensitivity of the interferometer is very high: synthesis maps of CO emission can be made at higher angular resolution than is possible with 21 cm HI emission. (iii) As the synthesized beams can resolve the molecular clouds observed in external galaxies, direct measurements of the cloud brightness temperature are possible.





Figures 1 and 2: Integrated CO intensity maps superposed on prints of the central region of M51. M51(2) is a field centered 20" north of the nucleus and M51(3) is centered 20" south. The center of each coordinate box is the field center. The maps are uncorrected for primary beam response which has a half-power diameter of 65".

OBSERVATION

The observations were made in the Spring of 1984, using 3 configurations of the 3-element interferometer, with (u, v) coverage out to a maximum of $\sim$20 thousand wavelengths. The 32-channel 1-MHz (2.6 Km/s) filter-bank was centered on V(LSR)=508.4 Km/s and 430.3 Km/s in the fields 20" north and south of the center of M51, respectively. Zero-spacing flux density was obtained with one of the 10.4-m telescopes of the interferometer.

RESULTS

As the integrated CO intensity maps shown in Figures 1 and 2, the CO emission is largely confined to arms coincident with the dust lanes, forming coherent structure as long as 3 kpc. The (synthesized-beam averaged) Rayleigh-Jeans brightness temperature of the CO emission evident on the synthesis maps ranges between 0.7 K and 4 K, corresponding to lower limits to the excitation temperature of between 4 and 7 K, averaged over 350 pc.

As the synthesis maps only contain a fraction ($\leq$0.4) of the zero spacing flux density, the observed CO distribution must be superposed on either a uniform distribution of background CO emission in M51 (on a scale larger than 30") or a collection of small cool clouds with a beam averaged brightness temperature < 0.7 K. The latter alternative is presumably a better approximation to the actual physical picture. The features evident in the synthesis maps thus resemble the giant molecular clouds (GMC) known in the disk of our Galaxy [4], but with more extreme properties (either more extended or warmer, or both).

There is an absence of the GMC component within 400 pc of the center of M51. This is unexpected, given that single telescope observations tend to indicate an exponential axisymmetric distribution of integrated CO intensity in late-type spiral galaxies [5, 4].

The velocity field of the CO emission is distorted with respect to that of an inclined differentially rotating disk. The origin of such distortion is not clear at present, but could be due to bar distribution in the nuclear gravitational potential.

DISCUSSION

The kpc-scale coherent structure seen in the GMC population in M51 (and IC342 [6]) implies that at least for GMC, random aggregates due to collisions of smaller clouds cannot be the only mechanism involved in their formation [7, 8]. A galactic scale alignment mechanism must also be involved. In the case of the IC342 nucleus, a bar potential is indicated. For M51, similar bar driving of the gas or shocks associated with a spiral density wave may be the cause. The observed non-circular velocity field will provide a clue. The observed minimum of GMC within the central 800 pc may also reflect the gas response to the same large scale alignment mechanism [9].

Unless the alignment mechanism maintains the same gas circulating within the large scale coherent structure, a short life-time for the GMC phase of the gas is implied. It will be important to combine these interferometer observations with the single telescope results [1] to determine better the relationship of the GMC phase, largely confined to arms, and the more generally distributed cooler gas.

Compared to galactic GMC, the CO brightness temperature of the GMC near the center of M51 implies a rather high gas temperature ($\geq$ 6 K averaged over 350 pc). Even higher gas temperature is indicated in the nuclear regions of IC342 [6] and M82 (unpublished) - $\geq$12 K averaged over $\sim$150 pc. Heating mechanisms to account for such high temperature need to be reviewed. As more aperture synthesis observations become available, the possible variations of the gas temperature at different galactic locations and between different galaxies will be understood better. The generally adopted proportionality of molecular gas mass and integrated CO intensity may have to be re-examined.

REFERENCES

[1] Rydbeck et al., this volume.
[2] Morimoto et al., this volume.
[3] Masson et al., this volume.
[4] Sanders, D.B., Solomon, P.N., Scoville, N.Z., 1984, Ap. J., 276, 182.
[5] Young, J., Scoville, N.Z., 1982, Ap. J., 258, 467.
[6] Lo et al., 1984, Ap. J. (Letters), 282, L59.
[7] Kwan, J., 1979, Ap. J., 229, 567.
[8] Scoville, N.Z., Hersh, K., 1979, Ap. J., 229, 578.
[9] Combes, F., Gerin, M., 1984, preprint.